CØØØ264

TECHNICAL PROPOSAL 6930-90

OPTICAL EQUIPMENT TEST KIT

SUBMITTED:
29 JANUARY 1971

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INSTRUCTIONS TO OFFEROR

1. The purpose of this form is to provide a standard format by which the offeror submits to the Government a summary of incurred and estimated costs *(and attached supporting information)* suitable for detailed review and analysis. Prior to the award of a contract resulting from this proposal, the offeror shall, under the conditions stated in ASPR 3-807.3, be required to submit a Certificate of Current Cost or Pricing Data *(see ASPR 3-807.3(e) and 3-807.4)*.

2. As part of the specific information required by this form, the offeror must submit with this form, and clearly identify as such, cost or pricing data *(that is, data which is verifiable and factual and otherwise as defined in ASPR 3-807.3(e))*. In addition, he must submit with this form any information reasonably required to explain the offeror's estimating process, including:

   a. The judgmental factors applied and the mathematical or other methods used in the estimate including those used in projecting from known data, and

   b. The contingencies used by the offeror in his proposed price.

3. When attachment of supporting cost or pricing data to this form is impracticable, the data will be specifically identified and described *(with schedules as appropriate)*, and made available to the contracting officer or his representative upon request.

4. The formats for the "Cost Elements" and the "Proposed Contract Estimate" are not intended as rigid requirements. These may be presented in different format with the prior approval of the contracting officer if required for more effective and efficient presentation. In all other respects this form will be completed and submitted without change.

5. By submission of this proposals offeror, if selected for negotiation, grants to the contracting officer, or his authorized representative, the right to examine, for the purpose of verifying the cost or pricing data submitted, those books, records, documents and other supporting data which will permit adequate evaluation of such cost or pricing data, along with the computation and projections used therein. This right may be exercised in connection with any negotiations prior to contract award.

FOOTNOTES

NOTE 1. Enter in this column those necessary and reasonable costs which in the judgment of the offeror will properly be incurred in the efficient performance of the contract. When any of the costs in this column have already been incurred *(e.g., on a letter contract or change order)*, describe them on an attached supporting schedule. When "preproduction" or "startup" costs are significant or when specifically requested in detail by the contracting officer, provide a full identification and explanation of same.

NOTE 2. The use of this column is optional for multiple line item proposals, except where the contracting officer determines that a separate DD Form 633 is required for selected line items.

NOTE 3. Attach separate pages as necessary and identify in this column the attachment in which the information supporting the specific cost element may be found. No standard format is prescribed; however, the cost or pricing data must be accurate, complete and current, and the judgment factors used in projecting from the data to the estimates must be stated in sufficient detail to enable the contracting officer to evaluate the proposal. For example, provide the basis used for pricing the bill of materials such as by vendor quotations, shop estimates, or invoice prices; the reason for use of overhead rates which depart significantly from experienced rates *(reduced volume, a planned major rearrangement, etc.)*; or justification for an increase in labor rates *(anticipated wage and salary increases, etc.)*. Identify and explain any contingencies which are included in the proposed price, such as anticipated cost of rejects and defective work, anticipated costs of engineering redesign and retesting, or anticipated technical difficulties in designing high-risk components.

NOTE 4. Provide a list of principal items within each category of material indicating known or anticipated source, quantity, unit price, competition obtained, and basis of establishing source and reasonableness of cost.

NOTE 5. Include material for the proposed contract other than material described in the other footnotes under the cost element entitled "Direct Material."

NOTE 6. Include parts, components, assemblies, and services to be produced or performed by other than you in accordance with your designs, specifications, or directions and applicable only to the prime contract.

NOTE 7. Include raw and processed material for the proposed contract in a form or state which requires further processing.

NOTE 8. Include standard commercial items normally fabricated in whole or in part by you which are generally stocked in inventory. Provide explanation for inclusion at other than the lower of cost or current market price.

NOTE 9. Include all materials sold or transferred between your plants, divisions or organizations under a common control at other than cost to the original transferror and provide explanation of pricing method used.

NOTE 10. Indicate the rates used and provide an appropriate explanation. Where agreement has been reached with Government representatives on the use of forward pricing rates, describe the nature of the agreement. Provide the method of computation and application of your overhead expense, including cost breakdown and showing trends and budgetary data as necessary to provide a basis for evaluation of the reasonableness of proposed rates.

NOTE 11. Include separate breakdown of costs.

NOTE 12. Provide a separate breakdown of labor by appropriate category and furnish basis for cost estimates.

NOTE 13. Include all other estimated costs *(e.g., special tooling, facilities, special test equipment, special plant rearrangement, preservation packaging and packing, spoilage and rework, and warranty)* which are not otherwise included. Identify separately each category of cost and provide supporting details. If the proposal is based on a F.O.B. destination price, indicate separately all outbound transportation costs included in total amount.

NOTE 14. If the total cost entered here is in excess of $250, provide on a separate page *(or on DD Form 783, Royalty Report)* the following information on each separate item of royalty or license fee: name and address of licensor; date of license agreement; patent numbers, patent application serial numbers, or other basis on which the royalty is payable; brief description, including any part or model numbers of each contract item or component on which the royalty is payable; percentage or dollar rate of royalty per unit; unit price of contract item; number of units; and total dollar amount of royalties. In addition, if specifically requested by the contracting officer, a copy of the current license agreement and identification of applicable claims of specific patents shall be provided.

NOTE 15. Selling price must include any applicable Federal excise tax on finished articles.

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The data set forth herein are submitted in response to an RFP and shall not be disclosed outside the Government or be duplicated, used or disclosed in whole or in part for any purpose other than to evaluate the proposal; provided, that if a contract is awarded to this offeror as a result of or in connection with the submission of such data, the Government shall have the right to duplicate, use or disclose these data to the extent provided in the contract. This restriction does not limit the Government's right to use information contained in such data if it is obtained from another source.

6930-90

TECHNICAL PROPOSAL

OPTICAL EQUIPMENT TEST KIT

SUBMITTED:
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TASK ABSTRACT

The objectives of this task are to design and develop a prototype Optical Equipment Test Kit. The task will be accomplished in five overlapping stages consisting of (1) Initial Equipment Selection, (2) Purchasing of Equipment, (3) Equipment Acceptance Testing, (4) Equipment Packaging, and (5) Publication of Procedures Manual. The selection of the components in the kit is based upon their portability, general usefulness, ease of component replacement, accuracy, and precision.

Cost Estimates:

	Kit No. 1
Direct Labor	
Engineering Overhead	
Material (includes travel)	
General and Administrative	
Fee	
Total	

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TABLE OF CONTENTS

SECTION I

INTRODUCTION

SECTION 1
INTRODUCTION

During the design and development stages of image-viewing systems and related equipment, it is essential to perform periodic field testing and evaluation. These tests will provide the program monitor with information necessary to determine the status of the equipment with respect to the program development schedule, budget, and fulfillment of program objectives. In addition, field tests provide information that can be used as a basis of comparison to results obtained in the final acceptance tests prior to government procurement of such systems.

As an aid to the program monitor in the equipment development stages, it is proposed that a prototype Optical Equipment Test Kit be developed for field use in the testing of image-viewing systems which include: Microstereoscopes, stereomicroscopes, light tables, projection viewers, and simple magnifiers. The selection of the testing components included in the kit will be based upon their (1) portability, (2) general usefulness, (3) ease of replacement, (4) accuracy and precision.

The Optical Equipment Test Kit will include testing devices for measurement or detection of optical parameters and performance qualities, physical quantities, and miscellaneous quantities relating to the general efficiency of the image-viewing system. These will include:

A. Optical Measurements

1. resolving power
2. magnification
3. field of view
4. flatness of field
5. pincushion/barrel distortion
6. astigmatism
7. parfocality
8. phoria
9. image runout

10. vignetting
11. interpupillary distance
12. light level

B. Physical Measurements

1. distance
2. temperature

C. Miscellaneous Measurements

1. image contrast
2. film-web tension

In addition, the data obtained from the physical measurements will provide accurate information with respect to mechanical quantities such as vibration, mensuration accuracy and orthogonality of X-Y translation systems.

The selection of the measuring devices chosen for the Optical Equipment Test Kit is based upon our past experience in programs directly related to the acquisition, processing, and interpretation of data for the purposes of image analysis, quality control, and overall evaluation of instrumentation. This includes areas utilizing photogrammetric instrumentation such as stereoplotters, microstereoscopes, stereomicroscopes, comparators, and microdensitometers with both analog and digital recording devices. In addition, we are presently under contract with your organization for the evaluation and development of optical testing procedures to be used for engineering acceptance testing of image-viewing instruments classed as binocular microstereoscopes. In partial fulfillment of the requirements of this Optical Testing Study, we have corresponded and visited with the leading manufacturers and users of this class of instrumentation in order to obtain a thorough knowledge and perform comparative evaluations of all available optical testing procedures. It is upon this knowledge of the state-of-the-art procedures that we have based our selection of the components of the Optical Equipment Test Kit.

All testing methods required for the proper utilization of the components in the Optical Equipment Test Kit will be described in detail in a manual to be published at the conclusion of this contract. All pertinent technical data concerning the kit components, such as expected component precision and probable test accuracy, will be included.

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SECTION 2

TECHNICAL DISCUSSION

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TECHNICAL DISCUSSION

A. BACKGROUND CONSIDERATIONS

In the development and specification of field testing procedures and materials, attention must be given to the desired evaluation criteria. Heuristically, these criteria will be dependent upon the degree of quality that can be established from the quantitative and/or qualitative data obtained through reasonable effort and cost. Some procedures may only require a two-level qualitative test, such as the verification of the presence or absence of optical aberrations or an indication that an anomaly exists. Other procedures may require a multilevel quantitative test, such as optical resolution measurements and magnification measurements.

In all cases, this degree of quality can be described by three aspects: (1) The precision of the measuring device, (2) the accuracy of the determination, and (3) the repeatability of the measurements obtained.[1*]

The precision is stated as the number of significant digits that are obtained from the measuring device: The greater the number of significant digits, the greater the precision.

Accuracy denotes the ability of the instrument to measure the true magnitude of a phenomenon. Associated with accuracy is the repeatability of the instrument. This is the ability of the instrument to yield identical measurements of a phenomenon that is stable during the time interval in which the measurements are performed.

It is possible for an instrument to be capable of high precision but only poor accuracy; conversely, it is possible for a measuring device to offer only low precision but good accuracy. Such possibilities are illustrated in Figure 1. Repeatability must be associated with accuracy, for if the repeatability of the measuring device is poor, then less confidence is placed upon any single measurement obtained from the measuring device. In most cases it is necessary to average a given sample of measurements

*All references are listed at end of this section.

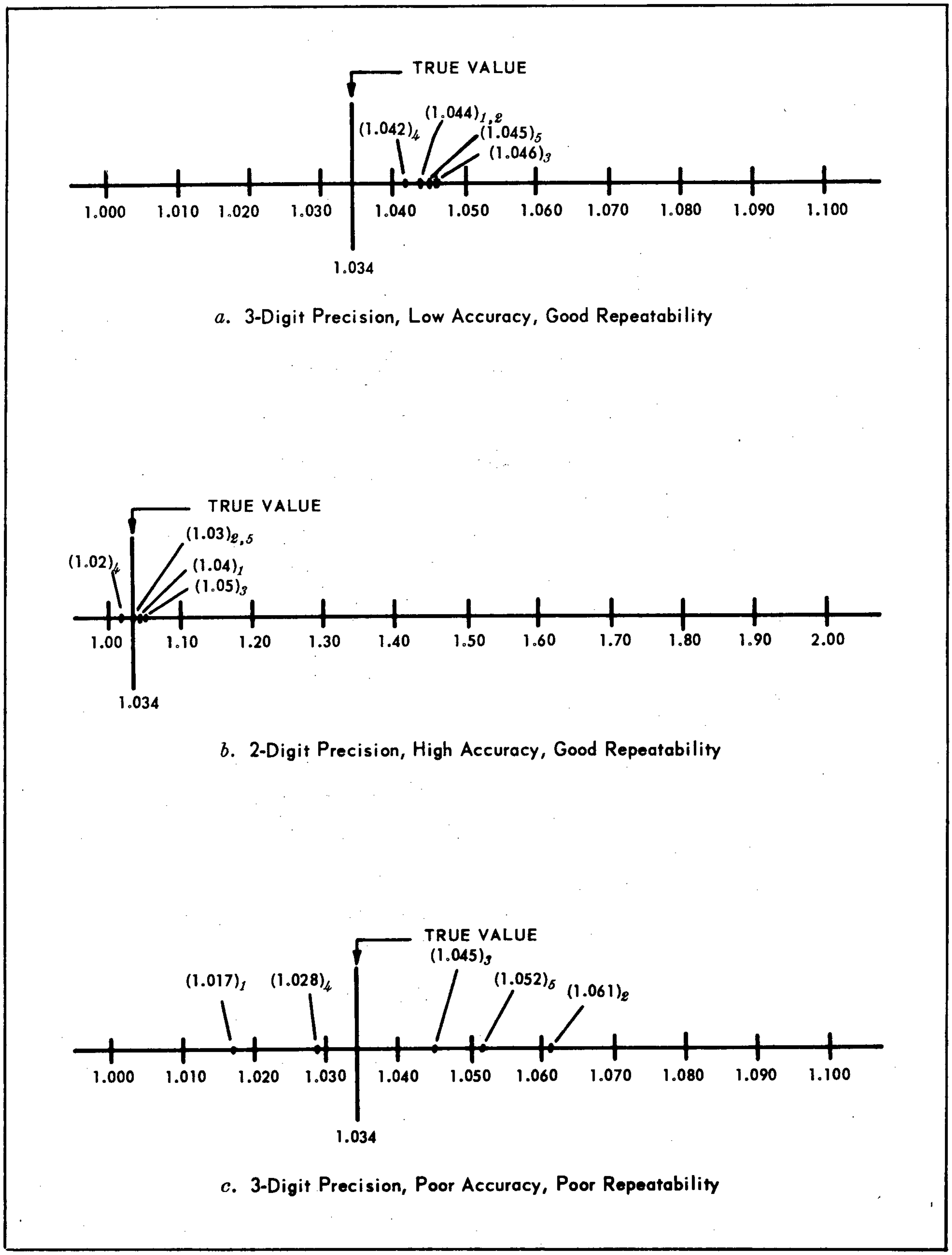

Figure 1. Accuracy, Precision and Repeatability, as Reflected by Five Measurements

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in order to obtain a single expectation of the true magnitude of the phenomenon being investigated in which an acceptable, subjective probability of truth can be placed.

The measuring devices and components, parameters and performance qualities, discussed in the following sections, were selected on the basis of their precision, accuracy, and repeatability with respect to their convenience, availability, and cost. Although it is understood, in some cases, that a higher quality measurement may be obtained, it is also understood that the cost of this additional quality becomes exceedingly high and beyond the needs of field testing devices.

B. OPTICAL MEASUREMENTS

1. Optical Characteristics: A majority of the optical systems used by the photo interpreter are designed to aid the naked eye. The basic instrument used in such systems is the microscope, whether it be of simple or compound design.

The optical characteristics of the microscope can be divided into optical parameters and performance qualities. This terminology would place optical magnifications, numerical aperture of the objective, and field of view of the eyepiece in the category of optical parameters. The performance qualities of the system include instrument resolution, image deformation, light transmission, and image contrast. Factors which affect the instrument resolution are optical alignment, astigmatism, flatness of field, chromatic aberrations, and target contrast. Factors which affect the image contrast include the light transmission efficiency within the field of view, optical alignment, and optical surface coatings. Table I summarizes this breakdown.

It is important to recognize that the instrument must be tested as a complete system to determine its quality. Individual lenses of the lens system certainly contribute to the overall performance of the instrument, but cases arise where one set of lenses works optimally only when used in tandem with another set. This situation very often exists with a microscope objective and its eyepiece.

2. Field Test Accuracy: When consideration is given to the accuracy required by field tests, it is instructive to fix an order of magnitude on objects detectable with the aided eye. To do this we fix the resolution of the unaided eye as one minute of arc

TABLE I

OPTICAL PARAMETERS

Magnification

Numerical Aperture

Field of View

PERFORMANCE QUALITIES

Qualities	Subfactors
Resolution	Optical Alignment
	Astigmatism
	Flatness of Field
	Chromatic Aberration
	Target Contrast
Image Contrast	Light Transmission
	Optical Alignment
	Optical Surface Coatings
Image Deformation	Lens Aberrations

and the optimum working focus distance for critical resolution as 10 inches.[2, 3, 4] From this a separation of 76 microns between two points can just be detected*, as shown in Figure 2a. Smaller separations can be seen with the aid of optical magnification, as shown in Figure 2b. This is expressed mathematically as follows:

$$1/S = OM/C \qquad (1)$$

where $C = 76$ microns is the distance in object space of the unaided eye, S is the resulting separation in object space of the aided eye, and OM is the optical magnification. Just as the eye is limited in resolution, so is any lens system. The Rayleigh criterion is used most often and is mathematically written in the following form:

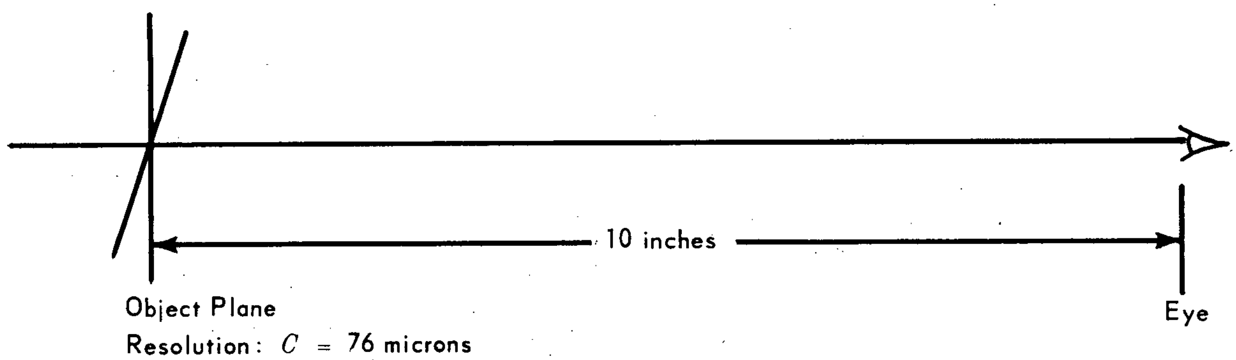
$$\theta = 0.61\ \bar{\lambda}/a \qquad (2)$$

*Although established leaders in the field of optics disagree on the exact resolution of the unaided eye, it is generally acceptable to be one minute of arc.[3, 4]

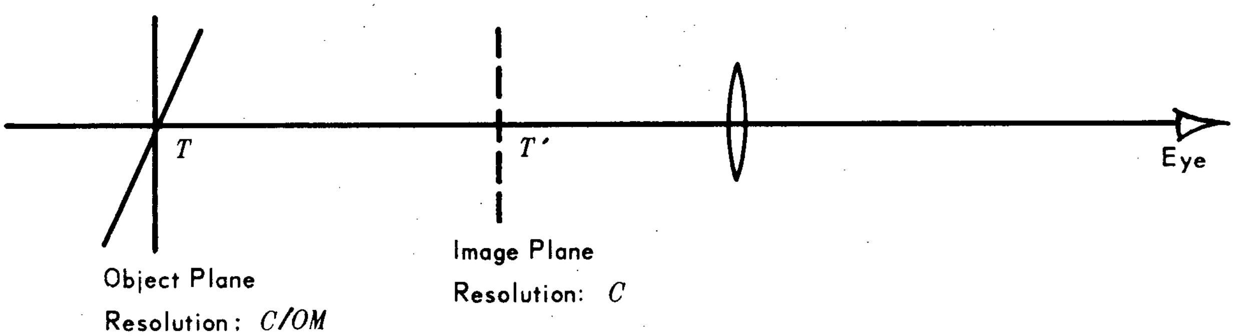
where θ = angular separation of two, just-resolvable points

$\bar{\lambda}$ = central wavelength of radiation

a = radius of the lens system aperture



a. Unaided Eye



b. Aided Eye

Figure 2. Limiting Resolution Considerations

Rearranging Eq. (2), by multiplying both sides by the lens system working distance WD, we obtain

$$S = 1.22\,\bar{\lambda}\,WD/2a \tag{3}$$

where $WD/2a$ is the equivalent f-number of the lens.

The quantity S is the resolvable separation, expressed in units consistent with the measured parameters.

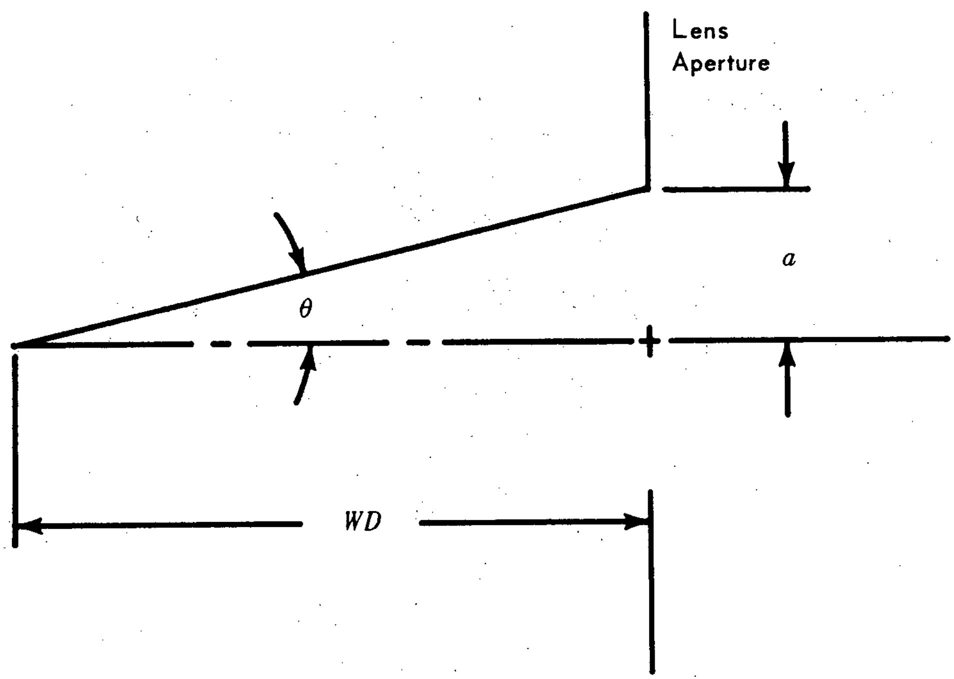
From Figure 3 we can make the approximate substitution that

$$WD/a = 1/n \sin\theta = 1/\text{N.A.} \tag{4}$$

This yields the resolvable separation S expressed in terms of the numerical aperture N.A., as follows:

$$\begin{aligned} S &= 1.22\,\bar{\lambda}/2\ \text{N.A.} \\ 1/S &= 2\ \text{N.A.}/1.22\,\bar{\lambda} \end{aligned} \tag{5}$$

where $1/S$ is the optical resolution of the system.



$$\text{N.A.} = n \sin\theta \approx n \tan\theta = n\,a/WD$$

$$n = \text{index of refraction of air} \approx 1.0$$

Figure 3. Illustration of Numerical Aperture (N.A.)

By equating the visual resolution and optical resolution, one may express the usable optical magnification as follows:

$$OM = 2C \text{ N.A.}/1.22\, \bar{\lambda} = 250 \tag{6}$$

where N.A. = 1.0

$\bar{\lambda} = 0.0005$ mm

Thus, with the aid of an optical instrument, the previous minimum visible object space distance, $C = 76$ microns, becomes

$$S = C/OM = 76/250 \approx 0.3 \text{ micron} \tag{7}$$

In addition, sound engineering suggests that an instrument be approximately 10 times better than the subject investigated. Hence, we can estimate the amount of tolerable distortion or astigmatism as 7.6 microns. With oil-immersion objectives the value of numerical aperture becomes greater (e.g., 1.4), increasing the magnification to approximately 300 and reducing the minimum visible object space to approximately 0.2 micron.

These values, while arrived at on the assumption of perfect lenses, do represent achievable numbers as evidenced by distortion plots found for reconnaissance mapping lenses.[5] They are also true for some microscope objectives which have been tested on the contractor's microscope lens bench.[6]

3. Optical Components: A program monitor — responsible for the field testing of prototype optical equipment such as microstereoscopes, stereomicroscopes, light tables, projection viewers, and simple magnifiers — requires the capability to evaluate such equipment in a way that will detect and in some instances quantify major discrepancies between actual performance and performance requirements. In addition, the program monitor is responsible for a wide range of optical capabilities which include determination of field of view, magnification, resolving power, field distortions, astigmatism, parfocality of stereoscopic instruments and zoom systems, phoria, image runout, interpupillary distance, eye relief, vignetting, field curvature and illumination.

The list of optical equipment, appearing in Table II on the pages that follow, is based on the foregoing considerations; these are the optical components proposed for inclusion in the field test kit. Note that estimates of equipment precision are given whereever applicable and that these estimates are based upon manufacturer's specifications.

4. Testing Methods: A thorough knowledge of the required optical testing methods must exist to insure the proper selection of the optical components in the field test kit. In addition, a mutual understanding must exist between the sponsor and the contractor concerning the basis upon which the particular optical components were selected. In view of these considerations, brief descriptions and comments concerning the optical testing methods to be utilized will now be presented.

Resolving Power

The absence of specifications for a standardized resolution target has led to the development of a variety of targets which have variable modulations, aspect ratios, and base transmittance levels for presumably equivalent resolution groups. Therefore, provided that the resolution range is adequate, consistent use of the same type of resolution target is most desirable. In addition, targets of reportedly high resolutions (greater than 1000 1/mm) have been found lacking in guaranteed quality specifications, while low-resolution targets of highly consistent and specified quality are of little use in the evaluation of high-resolution instruments.

Based upon these considerations, we have selected a target (7)* which presently appears to be the best compromise between specifications of quality and high resolution, while having a cost that is consistent with field testing equipment. The frequency range of this target is specified as 1 to 1000 1/mm with each single frequency pattern consisting of 15 clear bars on an opaque background. The target will be mounted on a 2-inch square glass plate with the following specifications: (a) maximum variation in width between the light and dark bars will be less than 5% over a range from 1 to 300 1/mm, and (b) the density difference will be greater than 2.0. It must be emphasized at this time, however, that we feel the final selection of a resolution target of higher quality and resolution range must await the development stages of the contract.

*Denotes item in Table II, Optical Equipment List.

TABLE II

OPTICAL EQUIPMENT LIST

	Item	Description	Precision
#1	Diopter telescope	This is one of the most important pieces of equipment in the kit. In order to accurately magnify microscope imagery for measurements of resolution, depth of focus, parfocalization, etc., a telescope of the highest quality is required. It must not introduce any additional aberrations into the system. Its uses are too numerous to give in this proposal. However, a more complete description of its applications will be furnished in the operator's manual supplied with the kit. The telescope selected has the decided advantage of "standardizing" the operator's eye. It eliminates confusing eye accommodation from the operator's eye and is adjustable to standardize the acuity of different individuals. An eyepiece reference scale allows a convenient method of returning to a particular individual's eye. It also includes a focusing adjustment calibrated from -6 to +8 diopters in 1/4 diopter increments for measuring accommodation ranges in adjustable binocular eyepieces. The 3X magnification allows the operator to check resolutions of instruments exceeding the resolution capability of the eye. It is felt that no compromise of either quality or versatility can be tolerated in fulfilling these specific requirements of the kit. This instrument will certainly not be a compromise in either respect.	1/4 diopter
#2	10X eyepiece	A 10X wide field eyepiece,which will accommodate the 21mm reticles supplied in this kit will be included. It will be calibrated under the contractor's supervision. However, calibration of this eyepiece is not considered necessary for the performance of any of the tests herein described. This calibration can optionally be deleted by the sponsor with an appropriate reduction in the cost of the kit. It should be noted that the only calibrations necessary must be performed on the equipment to be tested with the aid of a stage micrometer.	

TABLE II. (cont'd.)

	Item	Description	Precision
#3	Astigmatism and orthogonality target	This item will be custom manufactured. No standard targets for astigmatism could be found. The target consists of 29 cross lines located on the X and Y axes of the target plate as well as on the diagonals. For astigmatism the plate is designed to accommodate fields of view from 2mm to approximately 100mm. The cross lines will be approximately 5 microns wide. For economy, both the targets for astigmatism and orthogonality were put on the same plate. For orthogonality and linear dimensional check of mechanical stages, the positions of each cross line center will be accurate to ± 5 microns. On X and Y translations of 3.5 inches each, the accuracies at the right are applicable. The target will be a vacuum deposition of chrome on glass. This type of target is easy to view with transillumination and was chosen over other target materials because of its durability.	Orthogonality to better than 0.5 minute of arc. Length to ± 0.0002 inch.
#4	21mm reticle	0.5mm squares making a grid over entire field of view for distortion tests	0.5mm
#5	21mm reticle	Cross line scales 10mm long horizontally and vertically, each divided into 100 parts.	0.1mm
#6	21mm reticle	24 concentric circles, 0.5mm to 12mm diameter in 0.5mm increments	0.5mm

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TABLE II (cont'd.)

	Item	Description	Precision
#7	Resolution target	The resolution target will consist of three groups. Each group will contain 11 patterns covering ranges from 1 to 10 l/mm, 10 to 100 l/mm and 100 to 1000 l/mm respectively. Each single frequency pattern will contain 15 clear bars on an opaque background. Maximum variation in width between the light and dark bars will be less than 5% over the range from 1 to 300 l/mm. Density difference will be greater than 2.0. The target will be mounted on a 2 inch square glass plate.	Included in description
#8	Stage micrometer	For use in calibrating reticles and measuring magnification, 2mm scale divided into 200 0.01mm increments mounted on a 25mm x 75mm glass slide.	0.01mm
#9	Microscope grid	50mm x 50mm, 2mm squares. Accuracy ± 0.01mm overall, line widths 0.07mm and 0.15mm.	1.0mm
#10	Microscope grid	21mm disc, 0.1mm squares	0.1mm
#11	Large field grids	Several large grids of different dimensions will be provided. 9" x 9", 4" x 5" can be provided at relatively small cost for examining distortions. The size of the squares will be 1mm x 1mm or 0.2" x 0.2", depending on the overall size of the grid. The grids will be on a dimensionally stable Cronar base. Line widths will be .003" and .006". Spacing will be accurate to .0005".	1.0mm
#12	Translucent Scale	Made from Cronar base grid 2mm increments, 10cm long with numbers at each cm.	2mm

TABLE II (cont'd.)

	Item	Description	Precision
#13	Indicator and stand	A dial indicator with .001" divisions and 1" measuring range will be provided with a granite-base stand. The indicator can be moved by means of an adjustable arm to contact moving parts of instruments to be measured. Accurate to ± .0005" over entire range.	0.001"
#14	Light meter	The light meter will be a simple CdS exposure meter with an appropriate conversion chart for reading the light level of a light table.	The accuracy and precision of this instrument will be calculated by the contractor. Although not a laboratory precision instrument, it is felt that its precision is adequate for field testing.

The use of the resolution target for determining the system resolution is a highly subjective process. Several steps will be outlined in the procedures manual to "standardize" this operation in order to provide an acceptable level of repeatability. Proper use of the diopter telescope (1) is foremost in importance. Secondly, a set of preselected observations will be made, varying the orientation and location of the target within the field of view. The instrument will be evaluated at various magnifications and, where applicable, optical components (such as pechan prisms and rhomboid arms) will be rotated and their effect upon resolution will be noted.

Magnification

The magnification of an optical system will be measured by the superposition of an object plane scale on to an image plane scale. The selection of the appropriate object plane scale (8, 11, or 12) and image plane scale (5, 12, 15, or 16) will depend upon the classification of the instrument being tested. With microscopic viewing systems, an eyepiece (2) containing a measuring reticle may be used to measure the image, while a rear-screen projection system would utilize a direct measurement on the viewing screen. In all cases, the accuracy of the measurement is based upon the precision of the scales.

Field of View

The field of view will be measured by the subjective evaluation of the image of an appropriate scale (10, 11, or 12) placed in the object plane. The accuracy of the measurement is directly related to the precision of the scale placed in the object plane.

Flatness of Field

Viewing systems such as microscopes, which require an eye to produce a final image, do not have the same field flatness requirements as photographic systems. This is due to the accommodation of the eye. The primary effect of field curvature in such viewing systems is a loss of resolution near the extremities of the field of view. Thus, checking resolution at several points throughout the format will be the only recommended test that would detect objectionable field curvature.

For imaging systems such as rear-screen projectors, the dial indicator (13) would be placed against the focusing mechanism. A cross-line grid target (11) would then be focused sharply at different positions on the screen. A plot of screen position vs. focus position times system magnification would yield a graph of the field curvature.

Distortion

Field distortions will be detected by comparing an appropriate object grid of squares (4, 9, 10, 11) with either an eyepiece reticle grid (4, 10) or with a grid on the viewing screen (11). A calibrated reticle grid capable of actually measuring distortions throughout the format was not found as a standard off-the-shelf item. Its custom manufacture is considered to be beyond the scope and needs of field testing.

Astigmatism

The astigmatism of a system is not currently being measured, either qualitatively or quantitatively, by any generally accepted technique. The methods that do exist require a great amount of experience in optical measurement and, usually, a laboratory environment. Thus, the method that we propose is based primarily on a qualitataive test designed to indicate the presence or absence of astigmatism rather than an absolute measure of this quantity. Data relating to the change in focusing distance are obtained; however, it must be remembered that these data are based on a visual judgment as to best focusing conditions. (The method involves the use of a special target plate (3) to be viewed under normal viewing conditions, i.e., standard objective without the diopter telescope). If a difference between the best focus for vertical and horizontal lines is noticed in some areas of the field of view, then astigmatism can be assumed to exist. Measurements of the amount of the astigmatism can then be made using the diopter telescope (1) and the 0.001-inch dial indicator and stand (13). The difference between the best horizontal and vertical focus would be a representative measure of the amount of astigmatism present in the system.

Parfocality

Parfocality measurements of stereoscopic instruments, with and without zoom systems, can be obtained by: (a) Finding the best focus in one optical path of an appropriate object with the aid of a diopter telescope (1), (b) obtaining the best focus in the other optical path of the same object, and (c) recording the distance difference between the two best focus points using the dial gauge and stand (13). Zoom systems could be included by measuring the distance between best focus settings at various zoom magnifications utilizing the same equipment as above. Obviously, other systems could be measured utilizing the same methods.

Phoria

Phoria is primarily an anomaly of stereomicroscopes in that it occurs when the two optical axes do not superimpose at the same object point. It will be measured by: (a) Superimposing an object cross-line target (3) onto the center of a cross-line reticle of an eyepiece in one of the optical paths, (b) removing the eyepiece and placing it in the other optical path, and (c) measuring the amount of decentering that has taken place using a calibrated reticle scale (6).

Image Runout

Image runout occurs when a slightly decentered optical component is rotated, causing the image to be displayed with respect to the eyepiece field of view. It will be measured by: (a) Placing a crosshair target (3) in the object plane, (b) viewing the maximum vertical and horizontal image displacement of the target while rotating movable system components (such as pechan prism assemblies), and (c) measuring this image displacement using a calibrated reticle (5 or 6).

Vignetting

Vignetting is normally noticed with the wide-field 10X eyepiece in place while rotating the pechan prism. If present, the maximum and minimum field diameters are measured when vignetting appears to be most serious; the difference between these two values is a measure of the vignetting. The same technique as for measuring field of view is used.

Interpupillary Distance

Interpupillary distance has both a maximum and minimum value for most binocular instruments. A translucent scale (12) is placed above the eyepieces. The scale height is adjusted until the entrance pupils of the objectives are imaged on the scale. The separation of these images is the interpupillary distance. Subsequently, the eye relief may be measured with the metal 6-inch scale (15) as the distance between one of these images and the highest surface of the corresponding eyepiece.

Light Level

A very important evaluation criterion for light tables and optical equipment with self-contained illumination is the light level. A small, medium-priced CdS light meter (14) will be included with the kit as herein described. It may be optionally deleted with a small reduction in the quoted price of the kit. However, the light meter would enable the program monitor to obtain measurements of the light level of a diffuse source and check large sources such as light tables for evenness of illumination. It is felt that this particular meter is a good compromise between the real need for a light measuring device in field testing and the high cost of a more accurate and more versatile piece of equipment. However, in addition to providing this model in the first kit, a list of optional meters, their costs, versatility and accuracies will also be submitted as part of this contract for consideration in future kits.

C. PHYSICAL MEASUREMENTS

1. Physical Quantities: A field test kit should also include the ability to measure various physical quantities that may have an adverse effect on the reliability of an optical instrument. We propose that these measurements should include a versatile capability for measuring dimensions, such as length and height, a capability for measuring surface temperature, and a capability for measuring the vibration within a system. In addition, other distance measurement capability should be included to yield information concerning the linear translation and orthogonality of two-dimensional translation systems.

2. Equipment: To properly address such a wide variety of measurements, the following equipment (see Table III) was selected with the selection again based on a compromise in terms of versatility, precision, durability, and cost. (The item numbers are a continuation of the previous optical equipment item numbers.)

3. Testing Methods: The measurements that can be made utilizing the first four pieces of equipment (Items 15, 16, 17, and 18) are obvious in nature. Thus, the only

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TABLE III

MECHANICAL EQUIPMENT LIST

	Item	Description	Precision
#15	Machinist scale	6" steel rule with four scales on the four edges.	0.5mm, 0.01", 1/96", 1/64"
#16	Tape measure	6' retractible, metallic tape measure	1/8"
#17	Calipers	English and metric scale vernier calipers with inside, outside and depth capabilities to approximately 5".	1/128" or 0.1mm
#18	Surface thermometer	0° F to 300° F, magnetic clamp or silicone grease	± 2° F
#19	Tension tester	A 5 lb. capacity spring scale for use with film or film leaders with holes punched in them. The leaders or film to be supplied by the customer.	1 oz.
#20	Foeppl vibration target	This target consists of two rows of .001" diameter dots on a glass slide. The two rows diverge; the first two dots are .001" apart and the separation increases in .001" increments to .02".	0.001"

physical measurements that will be discussed are: (a) Vibration and (b) translation and orthogonality.

Vibration

For the measurement of mechanical vibration a Foeppl vibration graticule (20) has been included. Its design consists of two diverging rows of circular dots with diameters of 0.001 inch. The amount of vibration is determined by viewing the graticule and subjectively evaluating which pair of dots appear to merge together. The distance between this dot pair is the measure of the vibration of the system.

Translation and Orthogonality

A special target (3), which is also used for determination of astigmatism, will be used for determination of translation and orthogonality of a system. Measurement of the calibrated linear distances on this target will check out the linear accuracy of a translation system to 0.0002 inch. It will similarly check out orthogonality with an accuracy down to 0.5 minute of arc.

D. MISCELLANEOUS MEASUREMENTS

1. Equipment: In addition to the equipment listed above and intended for more or less specific capability requirements, an assortment of miscellaneous equipment will also be included (see Table IV).

A light source will be provided that has several versatile features for various applications. Both daylight and ground-glass filters will be supplied. The light source will be provided with its own adjustable stand for positioning. The illuminator contains a variable-focusing mechanism to provide either diffuse illumination with the ground glass or Kohler illumination when the ground glass is removed. A variable intensity control provides still another degree of freedom. To make the illuminator accessible to difficult places, an adjustable-angle, magnetically supported microscope mirror will also be provided. By aiming the light into the mirror, one can direct the beam up through an optical system easily, without moving the illuminator. The magnetic mirror support holds the mirror in any desired position. Since the specific pieces of equipment to be evaluated with this kit cannot be defined ahead of time, it is felt that the versatility of the illuminator and mirror described above is essential.

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TABLE IV

MISCELLANEOUS EQUIPMENT LIST

	Item	Description	Precision
#21	Illuminator	Variable intensity, variable position, variable focus light source.	N/A
#22	Variable angle reflector	1-1/2" diameter front surface mirror in adjustable position holder.	N/A
#23	N. D. filters	2" x 2" N. D. filters, 1.0, 1.5 and 2.0 N. D.; carbon suspension in gelatin	± 0.05 N. D.
#24	Step wedge	1" x 5-1/2" photographic silver 21-step tablet	Uncalibrated
#25	Spectral filters	Three Wratten color separation filters, 3" x 3"	N/A
#26	Polarizing filter	One 5" x 5" polarization filter, 0.01" thick	N/A
#27	Lens brush	1" width all camel hair lens and negative brush	N/A
#28	Hand magnifier	3" diameter, 8" focal length, handle	N/A
#29	Stop watch	30-minute elapsed time capacity; individual color coded stop, start, and reset buttons	1/10 sec
#30	Flashlight	A small flashlight with a well-directed beam	N/A
#31	Hole punch	A single-hole paper punch to make the holes necessary for the tension tester	N/A
#32	Case	Custom fitted with foam and straps where necessary to protect contents. Small enough to be carried on airplane trips.	N/A

Neutral density filters, 2 x 2 inches in size, will be supplied in densities of 1.0, 1.5, and 2.0. These are made of a carbon suspension in gelatin with suitable dyes for assuring neutrality. A 21-step density wedge from approximately 0.05 to 3.05 in steps of approximately 0.15 will be included for contrast measurements. This will be a conventional silver-on-film-base type and will be approximately 1 x 5-1/2-inches in size.

A stop watch will be provided with individual stop, start, and reset switches for ease of operation. A small camel hair brush, for dusting off film or optics, and a small flashlight will be included. A 5-pound spring tension scale will be used to measure web tension of film on light tables. Finally, an 8-inch focal length, 3-inch diameter hand-held magnifier can be used for close inspection of small components.

2. Testing Methods: The ability to measure light level, including uniformity of illumination over the viewing area, is a very basic requirement of any optical testing kit. For this reason, a light meter (14) is included among the optical components listed in Table II. In addition, however, factors which affect the light transmitted through a system, such as spectral content and polarization, must be given consideration since they will also have an effect on the results of the optical tests described in this proposal and, therefore, the evaluation of the ability of the prototype equipment to meet its design specifications.

It is not the intent to perform a detailed analysis of the effects of the wave nature of light on the results obtained by the previously described optical testing methods. It is important, however, to obtain some indication of the effects that factors such as spectral content and polarization have on these results.

It is well known that the resolution value obtained for an optical system may increase or decrease, depending upon the relationship that exists between the spectral content of material in the object plane and the spectral content of the light transmitted through the system. It is also known that the polarization of light transmitted through an optical system may change, depending upon the optical components (such as beam splitters) utilized in the system, and that the resolution value obtained for the system may change as a function of this polarization.

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In view of this, we propose the addition of three spectral filters and one polarization filter to the Optical Equipment Test Kit. Each may be used in addition to the equipment utilized in some of the previously described optical tests, such as the resolution test. A comparison of the results, with and without the individual filters, will then yield some indication of the effects that spectral content and polarization have on the prototype equipment. In addition, tests can be performed using the polarization filter at various orientations, in the plane perpendicular to the optical axis, so that some indication may be obtained concerning the existence of a strongly polarized component of the light transmitted by the system.

E. REFERENCES

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SECTION 3

WORK STATEMENT

SECTION 3
WORK STATEMENT

The requirements of this task will be fulfilled upon completion of the subtasks listed below. The order in which these subtasks are to be undertaken is as listed; however, some may be initiated or accomplished concurrently. In addition, frequent contact will be made with the contract monitor to insure that all of the components and test methods utilized address the specific needs of the sponsor.

A. FINAL EQUIPMENT SELECTION

Careful consideration of the sponsor's requirements, along with our prior experiences in closely related areas, guided us in drafting an initial list of test kit components. A survey of many manufacturers and suppliers by telephone and letter and an examination of brochures and catalogues helped us to refine our initial choices and provided us with the descriptions, precisions, and estimated costs used in this proposal.

The contractor's initial efforts will be directed toward the completion of this survey. Although the component information provided in this proposal is based on specific pieces of available hardware, final selection of many items will await the completion of the appropriate portions of this survey.

The survey will be completed on a part-time basis while work is being initiated on other subtasks. In addition, survey efforts on each individual component will be commensurate with its relative importance and cost.

B. PURCHASING OF EQUIPMENT

The purchasing of the smaller and less expensive items will begin upon contract initiation. The purchasing of the other components will be accomplished periodically, based upon the results found in the initial survey subtask. In all purchases a maximum effort will be made to obtain manufacturer's guarantees of equipment quality, especially concerning the durability, accuracy, and precision of the equipment. Time warranties will be requested whenever feasible. It is anticipated at this time that all items, with the possible exception of the resolution target, will be ordered within 30 days of contract initiation. The final choice of a prototype resolution target may exceed this time period slightly so that further inquiry may be made into the present specifications of the high-frequency groups. Note that this inquiry will not be based on the development of a state-of-the-art resolution target. It will be limited to an investigation of currently available specifications and procedures used to test these specifications.

C. EQUIPMENT ACCEPTANCE TESTING

Acceptance testing will be performed upon delivery of all prototype Optical Equipment Test Kit components. These testing procedures are considered very important to insure that the deliverable items have met the manufacturers' specifications concerning durability, accuracy, and precision. For some of the components, such as the coarse measuring scales, a simple inspection procedure should suffice, while for other components, such as the high-quality astigmatism and orthogonality target, more detailed testing procedures will be utilized. All acceptance testing requirements can be fulfilled at our facility. We have many years of experience in the areas of quality control and equipment evaluation and testing, and we have extremely accurate measuring capability through the use of Mann-Data Micro-Analyzers and Comparators.

D. EQUIPMENT PACKAGING

All Optical Equipment Test Kit components will be packaged in a single, portable, shock-proof, and weather-proof case. The portable case will be purchased with all internal packaging requirements designed and developed at our facility. Considerations will also be given to the development of a larger storage case, which would store all the components necessary to fill four or five portable cases, upon the request of the contract monitor.

E. PROCEDURES MANUAL

The contractor will publish an Optical Equipment Test Kit Manual which will describe, in detail, the proper procedures to be followed in performing the various optical, physical, and miscellaneous tests. In addition, detailed descriptions of each of the test kit components will be given, including the precision of the component and the expected measurement accuracy that should be obtained. The manual will be designed to fit in the field test kit with a binding suitable for the updating or addition of material.

SECTION 4

DELIVERABLE ITEMS

SECTION 4
DELIVERABLE ITEMS

The following are the deliverable items applicable to this task:

a. Monthly progress reports covering the work performed to date and the financial status of the program.

b. A procedures manual (20 copies), documenting in detail the procedures and equipment required for each field test.

c. An Optical Equipment Test Kit which presently contains the following items, described in further detail within Section 2 of this proposal:

1. Diopter telescope
2. 10X eyepiece
3. Astigmatism and orthogonality target
4. 21mm reticle
5. 21mm reticle
6. 21mm reticle
7. Resolution target
8. Stage micrometer
9. Microscope grid
10. Microscope grid
11. Large field grids (2)
12. Translucent scale
13. Indicator and stand
14. Light meter
15. Machinist scale
16. Tape measure
17. Calipers
18. Surface thermometer
19. Tension tester
20. Foeppl vibration target

21. Illuminator
22. Variable angle reflector
23. N. D. filters (3)
24. Step wedge
25. Spectral filters (3)
26. Polarizing filter
27. Lens brush
28. Hand magnifier
29. Stop watch
30. Flashlight
31. Hole punch
32. Case

SECTION 5

PROPOSED SCHEDULE

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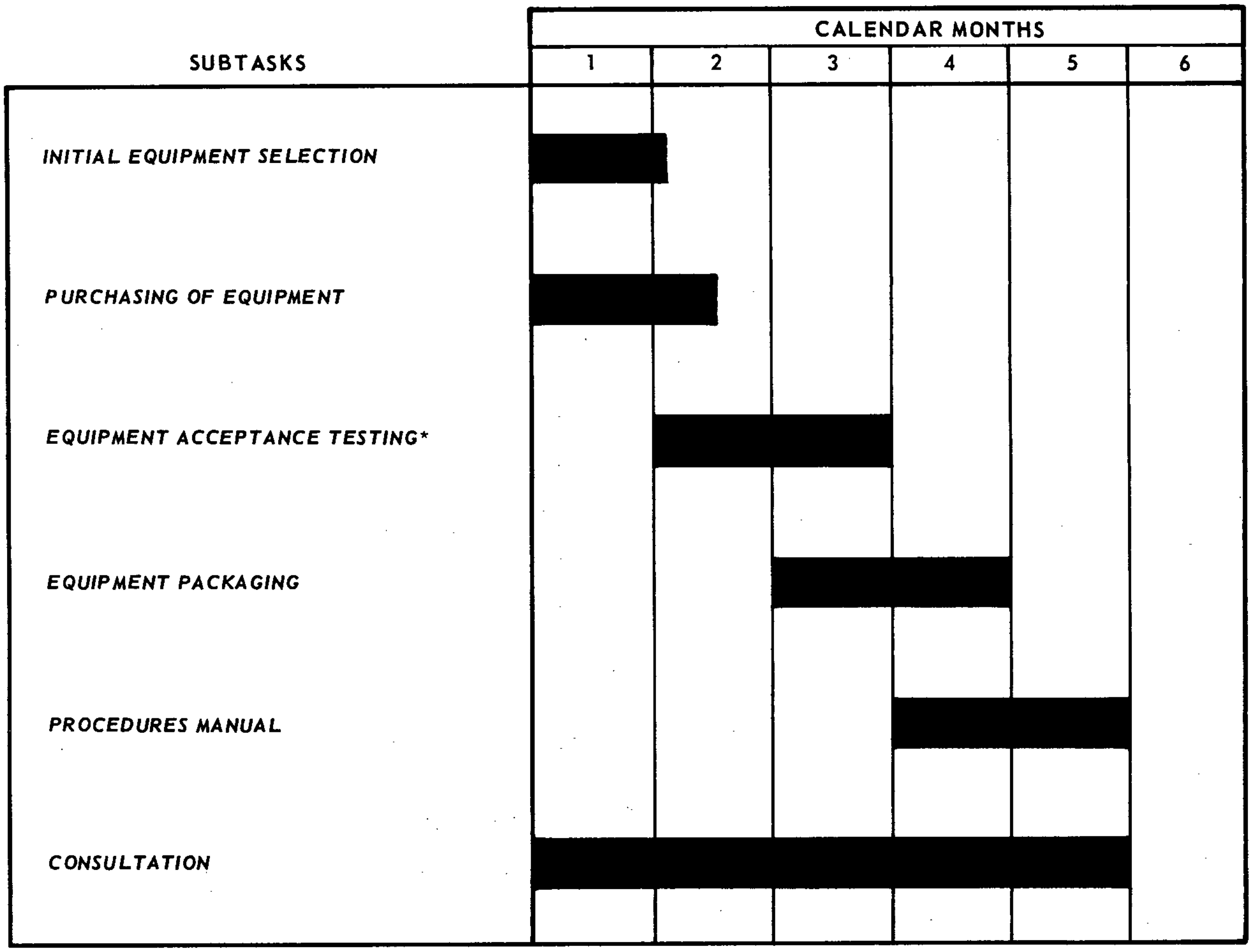
SECTION 5
PROPOSED SCHEDULE



*TIME PERIOD EXTENDED TO ALLOW FOR 30–DAY DELIVERY ON SPECIAL ITEMS.

The data set forth herein are submitted in response to an RFP and shall not be disclosed outside the Government or be duplicated, used or disclosed in whole or in part for any purpose other than to evaluate the proposal; provided, that if a contract is awarded to this offeror as a result of or in connection with the submission of such data, the Government shall have the right to duplicate, use or disclose these data to the extent provided in the contract. This restriction does not limit the Government's right to use information contained in such data if it is obtained from another source.